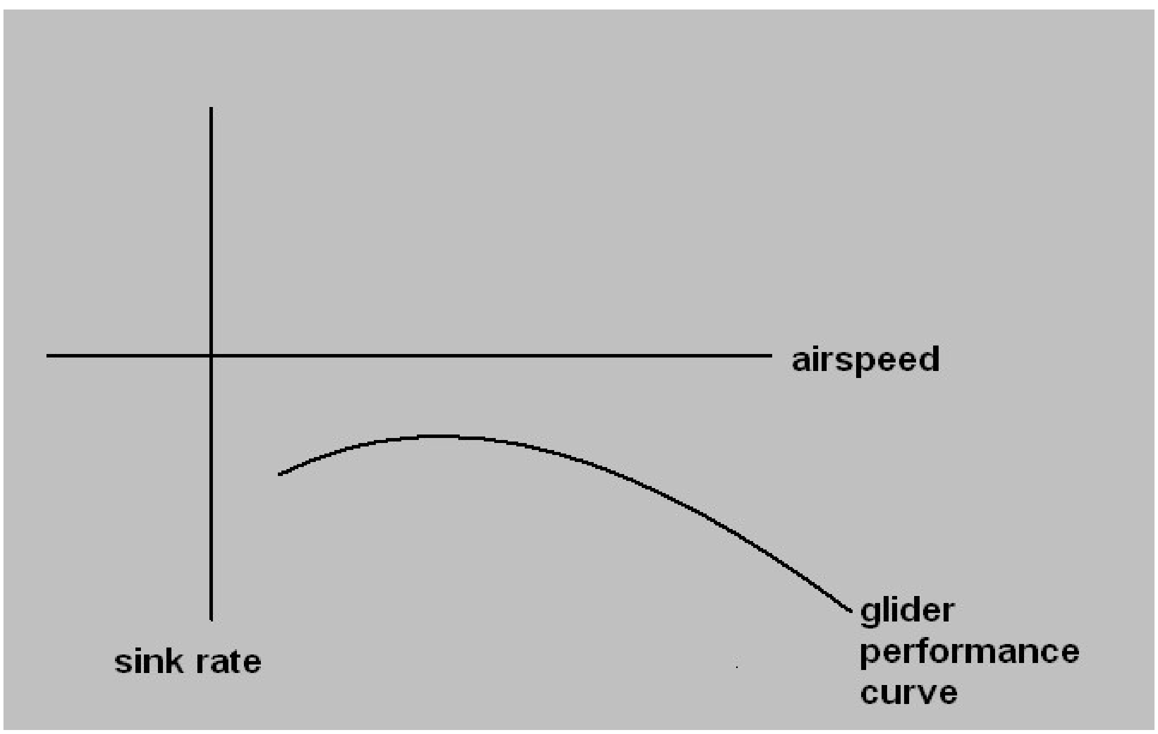
MacCready Theory: a quick overview

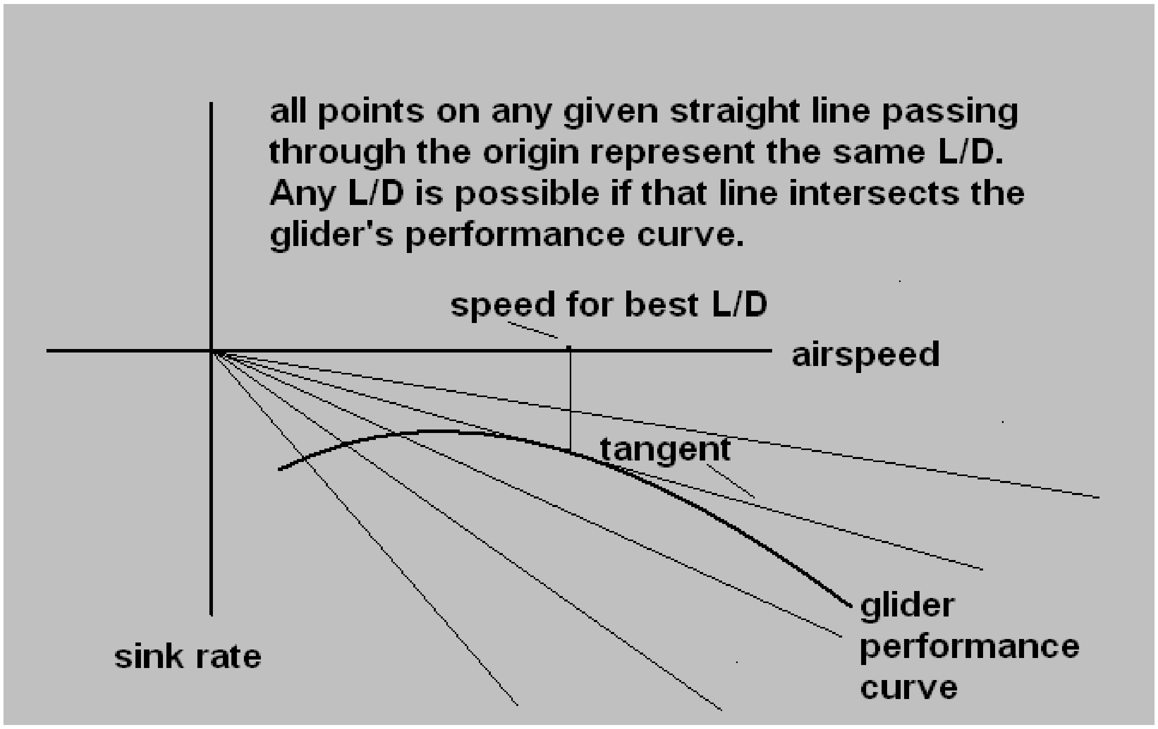
This discussion will merely summarize MacCready theory, but you will probably find that this will be all that's needed. (If you're really itching for more, consult Reichmann's classic book.) While every serious glider pilot should be familiar with the main points of MacCready theory, it is also important to note that the theory is an abstraction—a mathematical model designed to approximate reality in such a way as to make analysis simpler and more productive. In his analysis, MacCready treated an entire cross-country glider flight as if composed of a single glide followed by a single glide back up to the altitude at from which the glide started. This made mathematical analysis easier while neatly describing a typical flight, which includes many such segments—after all, we normally climb to the top of the convective layer, glide off on course, then find a new thermal and regain the lost altitude. Here, we'll briefly retrace his steps.

To begin with, let's review glider performance polars in general.

Here's what a typical glider performance graph looks like:



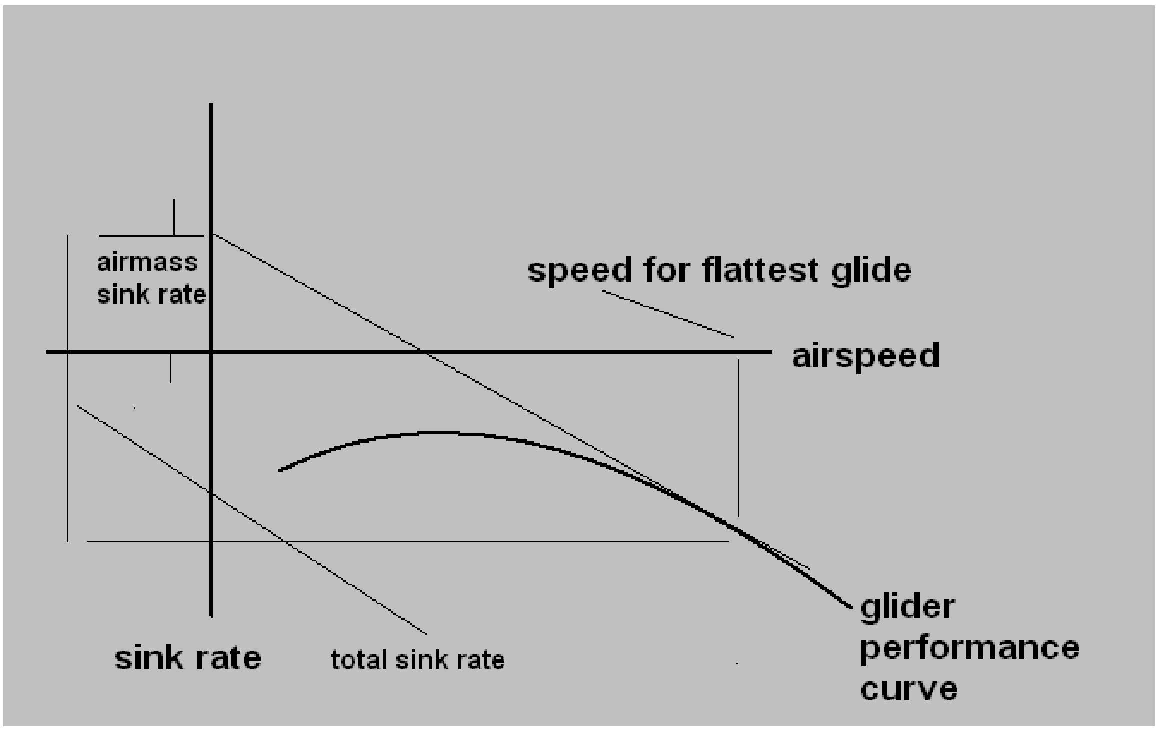
The highest point on the curve represents the minimum sink rate, and it's easy to determine the airspeed at which this occurs. But how do we find the flattest glide possible with this glider?
Here's the required construction:



Every straight line passing through the origin is associated with a particular glide ratio, but unless that line actually intersects the glider's performance curve, that glide ratio is beyond the glider's capabilities. (In the diagram above, I've drawn one line that doesn't intersect the glider performance curve at any point. The L/D represented by that particular line exceeds the best L/D of the glider depicted.) Any line that passes through the curve, however, represents an L/D of which the glider is capable. One line in particular, however, represents the highest L/D possible for that glider: the line that just grazes the glider's performance curve—or, in mathematical terms, the line that is tangent to the curve, as indicated in the diagram above.

To summarize, **the line that is tangent to the glider performance curve depicts the flattest glide possible with the given glider in still air** (at the gross weight for which the curve pertains.)

But suppose the glider is flying through sinking air. With respect to the ground, the glider's performance curve will move down by an amount equal to the air mass motion...but redrawing the curve would be a lot of work. So, instead, we can simply move the origin up by the same amount, and draw our tangent line from there:



The "total sink rate" in the diagram is the sum of the airmass sink rate and the glider's still-air sink rate at the same airspeed. As the construction makes obvious, the correct speed to fly in sinking air is faster than the speed for best L/D in still air... This is important information. Failure to follow this guidance is a good way to end up at low altitude without a good place to land within reach!

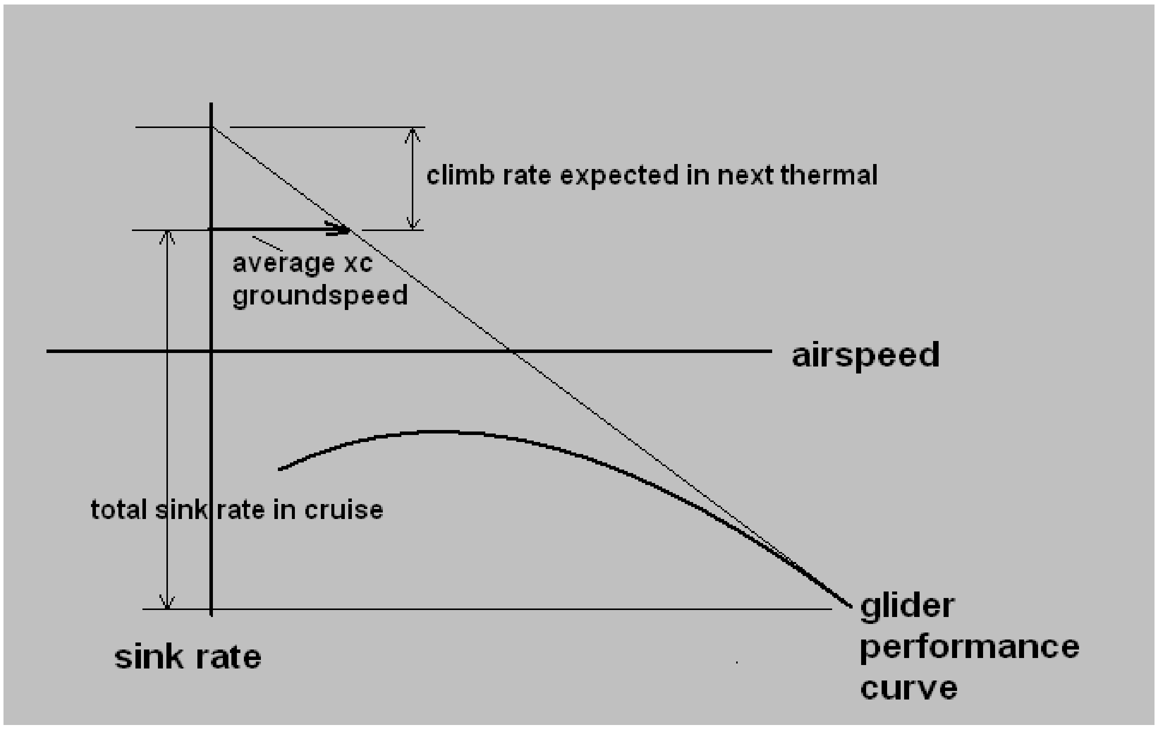
As you can imagine from studying the diagram, the correct speed to fly in rising air is below the speed for best L/D. It might even be productive to fly at the speed for minimum sink. It wouldn't be prudent to fly more slowly than this: the lack of control authority at very low speeds almost always outweighs the benefit of extremely slow flight.

So far we've only been discussing how to achieve the flattest glide possible under the existing conditions of lift or sink. MacCready goes a step further, and attempts

to answer the question of how to achieve the fastest glide possible (with the additional condition that the final altitude equals the starting altitude.)

The answer is startlingly simple—and instructive.

Here's how MacCready optimized the average cross-country speed:



As you might expect, MacCready specifies a higher interthermal glide speed, a speed that increases with any increase in the rate of climb expected in the next thermal. The construction for average cross-country groundspeed is really elegant; it makes use of the principle of similar triangles. (To see why it works, imagine a case in which the climb rate exactly equalled the total sink rate in cruise between thermals. In this case, you'd spend half your time cruising and half your time thermaling—and so your average groundspeed would be exactly half your cruise speed.) Can you see how your xc speed depends on climb rate?

By the way, perhaps you've noticed that we haven't even mentioned headwinds or tailwinds in this entire discussion. Why is that? Well, MacCready made the assumption that thermals drift with the wind, just as the glider does. (In many parts of the world that assumption is justified, but here in the Great Basin—where thermals are often tied to the topography—it isn't particularly accurate.)

Take another look at the diagram above. The ideal MacCready cruise speed is located by the point of tangency between the onstructed line and the glider's performance curve. However, it is in the nature of tangents that a minor speed

deviation isn't particularly significant; as you can see from the diagram, a small change in airspeed won't really make much difference in the average cross-country groundspeed...
However, the average groundspeed is extremely sensitive to changes in the rate of climb in the next thermal! In fact, it's just about proportional to climb rate—meaning that inefficient thermal technique, perhaps cutting your climb rate in half, will just about cut your groundspeed in half, too.

The single most important thing you can do to improve your cross-country speed is to learn to thermal and climb as efficiently as possible.

While MacCready theory is something with which every soaring pilot should be familiar, it is important to understand its many limitations:

1) Perhaps the most important limitation to MacCready theory is that it assumes the pilot knows the actual rate of climb that will be experienced in the next thermal. This is pretty optimisitic: most pilots don't even know their average rate of climb in the last thermal!
2) Similarly, MacCready assumes the pilot will unerringly fly directly into the next thermal and will never have to slow down and spend time (and altitude) looking for it. We should all be so lucky!
3) MacCready theory implicitly assumes that there is always a safe landing spot (which won't be needed, anyway!) within easy reach. This assumption is reasonable in many parts of the world--but not here in the Great Basin where we often have entire mountain ranges to cross between successive landing spots.
4) In-flight guidance provided through MacCready theory is generally presented in terms of speed-to-fly commands, but as we've already seen, rather large speed deviations often result in quite minor average groundspeed losses (while also allowing much more time to think and both time and altitude to find new thermals, etc.) Unfortunately, the typical speed-to-fly presentation gives no information at all about these trade-offs, but simply urges the pilot to fly faster, even when there is very little advantage to doing so—and often, when there is much to be gained by flying more slowly than MacCready recommends.
5) MacCready theory was developed in terms of a classic 'sawtooth' flight profile: straight glides interrupted by circling climbs in thermals. Other strategies, such as dolphin flying, aren't directly addressed—yet dolphin flying holds the key to averaging significantly higher groundspeeds.

Does this mean that MacCready theory is useless? Not at all! MacCready provides a terrific starting point for developing your own cross-country style, and—above all—it makes clear that the key to efficient cross-country soaring is achieving the

highest rate of climb possible in every thermal—and THAT'S exactly why we're all here today!